PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improved Method of Preparing a Concrete Structure

We, MIL-WIS ENGINEERING, INC., a Corporation organized under the laws of the State of Wisconsin, United States of America, of 4235, North 127th Street, Brookfield, Wisconsin, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an improved method of casting a concrete structure wherein a hollow shell of the proposed structure is cast, the shell then being connected to other similarly cast shells to define the skeleton of the structure.

The prior art has known for quite some time of a technique for making a concrete structure wherein concrete castings are made and assembled into a hollow skeleton defining the ultimate structure. A concrete core is then cast into the hollow portions of the skeleton. Members such as beams and columns may be made and connected to each other in such fashion that the hollow portions are connected. Steel reinforcement is used where desired.

One problem with prior art casting techniques of the character referre to has been the securement of adequate bonding between the juxtaposed surfaces of the shell and the core. The problem arises because the concrete in the shell is generally completely set before the core is poured and presents a smooth surface unsatisfactory for achieving a surface-to-surface bond of suitable character. Past techniques for improving the core to shell connection have generally overlooked improvement of the bonding and have instead involved complicated in situ casting using ordinary forms and hollow shells together; ignoring the problem entirely; or, most commonly, the embedding of steel wires, studs, and the like (i.e. keying means) in the inside wall of the shell. These wires and studs extend from the shell into the core and are intended to key the two together. However. the important effect of surface-to surface bonding along the respective juxtaposed surfaces of the shell and core has not been fully appreciated. One reason for this inadequate bonding has been the laitance of green concrete, i.e., the accumulation of fine particles of sand, aggregate and cement upon the surface of the casting.

The bond wall of the prior art shell is inaccessible during casting and is set after casting thereby raising a number of problems where attempts are made to insert keying means. For instance, after the shell is set enough to remove forms, the keying means cannot be inserted into the shell, it no longer being plastic. Inasmuch as some form of a mold is used in casting the shell, it is a problem during moulding to insert a stud or other keying means into plastic concrete through the mold wall while still retaining the ability to readily assemble and dismantle the mold without destroying the forms or mold walls. It has been proposed to employ flat slabs with inserts which may partially solve this problem but has a drawback in requiring extra labour and special fittings and assembly techniques in order to arrive at satisfactory shell members.

A further disadvantage in using keying means such as studs is the increased difficulty in placing reinforcing steel in the shell due to interference by the keying means.

Although the shell and core type of construction has been known for upwards of 50 years, the aforementioned disadvantages have militated against its use. Generally speaking, this has become an abandoned art, despite the advantages of eliminating expensive form construction and despite the advent of

precast and prestressed concrete over which the shell-and-core technique has numerous advantages including the greater ease of handling lighter weight castings and in terms of providing an integral core extending through the final building.

More than 36 years ago, Nathan C. Johnson devised a method and a composition for treating concrete whereby a rough textured surface with the aggregate exposed could be produced. The art has considered this technique as useful for architectural but not structural purposes. Johnson's modus operandi entailed using a retarder to retard the setting of the cementitious material at the surface of a concrete casting in such fashion that the remainder of the casting mold set to an extent where a subsequent simple washing or brushing operation would remove the unset cementitious material leaving exposed a substantial surface of aggregate and roughened cement.

Despite the availability for such an extensive time interval to all of the prior art teachings, no one has recognized the advantages in shell-and-core construction of retarding the setting of the cementitious material on the surface of the inside of a shell whereby the problems of placing the studs, cleaning off parting material, casting the core using reinforcing and vibrators, and so forth, are eliminated. This is true despite the advent of precast and pre-stressed concrete.

The invention can be practiced in producing shell-and-core structures that are prestressed, post-tensioned or unstressed.

A coating of a retarder is applied to the inside wall of the form or mould used to cast a shell. When the plastic concrete is then poured into the assembled mould, a zone of retarded setting occurs adjacent the inside wall. Removal of the mould or form at an appropriate time provides a shell wherein a thin retarded zone on the inner wall is provided, the remainder of the concrete of the shell being set sufficiently to permit removal of the forms or moulds. The laitance, in large part the relatively unset or still-plastic cementitious material in the retarded zone is then removed by any suitable means such as washing, brushing, or a combination thereof, thus leaving a wall of exposed aggregate to which the core when poured can readily bond itself.

According to the present invention there is provided a method of building a concrete structure formed of a number of concrete shells interconnected by a core bonded to inner walls of the shells, which comprises the steps of aligning the shells in the structure so that they form a core receiving chamber and pouring concrete into the core receiving chamber in juxtaposed intimate bonding relation with the inner walls of the shells wherein the shells are each formed by assembling a number of forms to define the shell, applying a retarder to that portion of the forms defining the inner walls of the concrete shell, pouring concrete into the forms, allowing the concrete to set until the main portion of the concrete shell is set sufficiently to permit removal of the forms, removing the forms from the concrete shell and removing cementitious material and retarder from the inner walls of the concrete shell thereby exposing the aggregate embedded in the set concrete.

Embodiments of the present invention will now be described, by way of example with reference to the accompanying drawings in which:—

Figure 1 represents a plan cross section of a rectangular column showing the disposition of the form and the retarder.

Figure 2 represents a plan cross section of the column of Figure 1 during casting where the form is filled with concrete and wherein a retarded zone is formed,

Figure 3 is a perspective representation of a cast shell, formed pursuant to Figures 1 and 2, after the moulds or forms have been removed, and further showing one manner of removing the plastic cementitious material to expose the aggregate on the wall adjacent the core,

Fig. 4 is a plan cross section of the element of Fig. 3 after the core has been filled with reinforcing steel and plastic concrete such as during the construction of a building or the like,

Fig. 5 is a representation of a typical cross section through the shell of a beam or joist, formed with reinforcing steel, and providing bond walls adjacent the portion where the core is to be disposed,

Fig. 6 represents a circular column which may be formed in a fashion similar to the process outlined in Figs. 1—4,

Fig. 7 represents a typical assembly of a concrete shell column and beam members at the corner of a building,

Fig. 8 represents an embodiment of the invention wherein it is desired to provide a fillet between a column and a beam, joist or the like.

Fig. 9 represents one manner of joining a beam shell to a column shell, and

Fig. 10 represents a cross section through one embodiment of a floor span fabricated in accordance with the invention.

Throughout the following disclosure, for the sake of convenience, similar parts will be referred to by the same number.

The procedure followed in connection with the present invention is best illustrated in Figs. 1—4, while Figs. 5—8 show various structural variations susceptible to being practiced by the instant invention along with exemplary application (Fig. 7) to a structure.

Referring first to Fig. 1, there is shown an assembled form 1 having outer form walls 2, 4, 6 and 8 connected together in any

suitable fashion, as by clamps or even nails. The form walls may be constructed of wood, plywood, sheet metal, sheet metal coated wood of one sort or another, or the like. The inside of the outer form walls are coated with a material suitable for preventing the adhesion of concrete thereto. An inner wall assembly part of the form 1, is constituted of the various walls 9, 11, 13 and 15 which may be formed of similar materials and connected in any suitable fashion as by nailing together or the like.

The inner wall formed by members 9—15 is responsible for defining the "bond wall" 27 constituting the surface which the core is ultimately to be placed in contact with. The bond wall 27 is referred to at a later point in connection with Fig. 3 and other Figures.

It will be observed from Fig. 1 that a generally annular construction is provided whereby a continuous enclosed ring of concrete of a suitable shape will be formed by the casting process. Other shapes, as described below in connection with Fig. 5, are formed in a similar fashion and do not need to be annular. However, for columns and other compression members it is desired to provide an annular cross section of any suitable shape such as rectangular, circular, oval, egg shaped, or the like.

Returning to Fig. 1, the inner form walls 9—15 are coated with a retarder 17 whereupon the bond wall 27 will ultimately be formed after succeeding operational steps are carried out. A suitable retarder is molasses. Other retarders having a hydrocarbon base are also suitable.

As a general rule structural concrete elements are formed of steel-reinforcing concrete, therefore in the ordinary situation steel reinforcement 20 will be disposed in the form. The reinforcement 20 is advantageously steel mesh to enable casting a thin-wall shell which is lighter in weight and quite easy to handle. The bulk of the reinforcing steel is thereafter disposed in the core (Figs. 4, 7). After the form or mould of Fig. 1 is assembled, the bond wall coated with the retarder 17, and the reinforcement 20 is set in place, concrete is poured into the annulus between the outer wall comprising members 2—8 and the inner wall comprising members 9—15. The concrete then proceeds to set, and as shown in Fig. 2, a retarded zone 27R is formed. The retarded zone constitutes cementitoius material and some aggregate, depending on the penetration of the retarded effect into the shell. Generally, however, the retarded zone extends only a small way into the annulus or shell. Thus, the retarded zone 27R comprises mainly cement, sand, some small aggregate and of course the usual water as well as the retarder. The larger aggregate is embedded in the concrete which is setting at the usual rate.

The shell is now allowed to set at least until that portion of the shell outside of the retarder influence is sufficiently strong to be self-supporting upon the removal of the forms. The forms are removed upon or after reaching the degree of set indicated.

After the major portion of shell has set, and while the retarder is still maintaining the retarded zone in a relatively unset condition, the form 1 is removed from the shell and the unset cementitious material on the bond wall is removed in some suitable fashion to provide the bond wall 27 as best seen in Fig. 3. A suitable manner of removing the retarded material comprises washing the same with water 32 emitted from a hose 30 or the like. Brushing can on occasion be used, preferably combined with washing. The stream of water 32 can be adjusted in pressure to avoid damaging the shell.

As best seen in Fig. 4, the shell produced as a result of the previously described steps is preferably now moved to the construction site and connected to other structural elements in any suitable fashion, e.g. as described below with respect to Fig. 7. Once the shell is in place, e.g. if a column is disposed on its footing or other bottom member, core reinforcement 34 is placed, and adjacent members, e.g. beams and joists, are connected thereto, the core is cast by pouring plastic concrete into the various interconnected cores. An integral core interconnecting the various column and beam shells is thus formed and includes in the previously described column shell a core 31 having embedded therein suitable steel core reinforcement 34, which is bonded continuously around the bond wall 27 to the column shell 21. In similar fashion the shell-and-core beams include reinforcing steel embedded in the beam core which is bonded to the beam bond wall 47 (Fig. 5).

The various structural cross sections may be annular as explained with reference to Figs. 1—4, or may be of channel section as illustrated in Figs. 5 and 10.

Fig. 5 represents a typical shell cross section for a beam, joist or other such member, and comprises a channel-shaped reinforced concrete structure in the preferred embodiment. The beam cross section 41 of Fig. 5 has te reinforcing steel 40 disposed therein in a suitable fashion for a reinforced concrete beam. The bond wall 47 is preferably continuous around the internal portion of the channel cross section, whereby a trough is defined. Thus, when the beam is disposed in its usual horizontal position, reinforcing steel is supported in the trough, (see Fig. 7 for example) and then the concrete is poured in and bonds itself to the walls 47 in the fashion heretofore mentioned. The beam 41 is cast by providing a mould of suitable shape,

wherein the portion of the mould or form defining the bond walls 47 is coated with a retarder of the character mentioned above, and after the major portion of the beam shell 41 has set the forms are removed and the bond walls cleansed of the retarded-setting cementitious material.

Fig. 6 represents a circular column or other structural member which is formed in a fashion similar to that mentioned above and is illustrated to emphasize the wide variety of structural shapes and elements to which the invention is applicable. For the sake of convenience, the various structural portions of the column in Fig. 6 are designated by the same numbers employed in connection with Figs. 3 and 4.

Figs. 7—10 represent typical structural assemblies. Fig. 7 is self-explanatory in light of the foregoing and illustrates one manner of disposing the column and beam reinforcing steel bars 34, 44.

Fig. 8 represents a capital, i.e. a means of joining beams to a column by a filleted joint comprising a fillet shell 51 cast in a frusto-conical or frusto-pyramidal shape, employing the procedures outlined above. The fillet shell is preferably of reinforced concrete and is disposed with the small end down on top of a column member 21 in such fashion that the column bond wall 27 is aligned with the fillet bond wall 57 to present a smoothly changing contour in the region of the fillet shell. Beams 41 (see Fig. 5) are mounted atop the fillet shell with the bottom bond wall 47 coming into alignment with the fillet bond wall 57. The sides 42, 46 of the respective right and left hand beams extend past their respective bottoms to approximately the centre line of the column-fillet-beam assembly of Fig. 8 where sides 42, 45 of each beam meet with their counterparts on the other beam.

After the elements thereof are assembled in the fashion described, reinforcing steel 34 and 44 (Fig. 7) is disposed in the columns and beams and properly keyed one to another. Thereafter concrete is poured into the core sections of the beams and column so that an integral core bonded to all of the shells is formed. On some occasions it may be preferred to cast the fillet in place so that there is really no fillet shell, but instead the entire fillet is integral with the column and beam construction. This is more complicated inasmuch as it requires supporting the beam shells independently of the column during the time that the preparations are being made for casting, and also in that it requires the construction of a form at the site.

Fig. 9 represents one manner of joining a beam shell to a column when at least one insert 80 is cast into the upper end of the column shell. The insert receives a bolt or stud 82 which is passed through a hole or slot 49 which is cast into the beam shell and secured in further engagement with the insert 80. Where a stud is used, a nut 83 is secured in appropriate fashion. A washer 84 is advantageously employed to span the edges of the hole 49 in such fashion as to provide bearing surfaces between the nut or bolthead and the edges of the slot 49.

Fig. 10 represents one embodiment of a floor cast in accordance with the invention using floor shells 61 which are shaped somewhat like channels with the web extending past the confines of the channel flanges. In this fashion, the web extensions form troughs between the flanges of the floor shells 61 and a bond wall 67 is provided. Reinforcing steel 64 is provided in an appropriate fashion. In fitting the floor shells 61 together, it is ordinarily necessary to cut one shell 61*a* longitudinally, or to cast a shell 61*a* of different width to provide an appropriate fit with the beam 41 on at least one side of the structure being considered.

A conduit 69 may conveniently be formed using the floor shells 61 by disposing a slab 68 on top of the space between the flanges. The slab 68 advantageously has tapered edges 68*a* whereby a snug fit with the adjoining portions of the floor-shell is realized. The conduit 69 can be employed for electrical leads, water pipes, air conditioning ducts and the like. In the instance of air conditioning ducts it is preferred to provide a smooth wall of the duct whereupon the bond wall construction is either omitted or the conduit space 69 is lined with an appropriate material such as a galvanized sheet metal.

It will be observed from Fig. 10 that the beam shell 41 has its inside edge 42*c* made substantially shorter than the opposing edge 46, whereby the floor shells and the floor 71 are readily accommodated.

The arrangement of Fig. 10 advantageously provides a maximum thickness of the core member constituting floor 71 in those regions where the precast sections adjoin each other. Also, the hollow portion 69 is provided so that an efficient structural section results from having less material along the neutral axis.

The shell ribs or flanges may preferably extend vertically to a height appropriate for supporting "temperature steel" which is disposed at right angles to the shells to prevent cracking of the floor 71 due to temperature stresses. For example, the temperature steel may be laid directly on top of the ribs thereby eliminating the need for using "high chairs" or "bolsters" for supporting the temperature steel in place. Generally the slab 68 would be supported flush with the tops of the flanges or ribs so the temperature steel reinforcement can lay on top of the ribs.

Similarly, the placement of reinforcing steel to oppose tensile stresses is simplified. Such reinforcement is cast in the shells 61,

or placed in the space between the ribs thereof to accomodate tensile forces acting along the top or bottom of the composite floor structure 61, 71. Thus steel can be easily placed to resist both positive and negative moments.

Compression tests have been made comparing sample columns having a smooth bond wall on the one hand with an exposed aggregate bond wall on the other hand. These tests reveal that the smooth bond wall column failed at lower loads and unit stress than did the exposed aggregate bond wall samples. Moreover, the exposed aggregate bond wall samples failed in the classical fashion along a plane representing the combination of compression and shear forces acting on the cross section of the column. Furthermore, the exposed aggregate bond wall samples failed as a unit as if they had been cast in one piece, whereas, the samples having a smooth bond wall tended to shell or spall whereby sections of the outer shell broke away from the core before or at failure.

A wide number of retarders are applicable in the course of practicing the present invention. These are commercially available for use under varying weather conditions, with different cements, and the like. Several retarders have been mentioned above. Other retarders include starches or cellulose products, acids or salts or acids containing one or more hydroxyl groups, and carbohydrates, to name a few. On occasion a retarder may be one of the preparations used in retarding the setting of oil well cementing slurries. A generalized discussion of retarders and their use is found in "Admixtures for Concrete" in the October, 1954 Journal of The American Concrete Institute (Vol. 26, No. 2, page 113).

The present invention offers a number of advantages over the cast-in-place concrete, that is, plastic concrete which is formed by assembling forms in situ and casting the concrete. These have been rather generally mentioned above. Faster construction is realized because the present invention eliminates on-site time spent building and removing forms, and because the shell-and-core technique is less subject to such uncontrollable conditions such as weather, labour disputes, and the like. Lower costs may be realised by practicing the present invention because less on-sited labour is require, there is little or no necessity to finish the concrete by rubbing it or the like, and clean-up costs are lower as there is generally less clutter at the construction site due to having forming materials and equipment strewn around.

The present invention more readily achieves better appearance in the course of creating a particular structure, by comparison with the cast-in-place procedure. For one thing, the forms can be more rigidly supported while casting the shell, hence the flexing or bulging of the forms is less likely to occur and once the shell sets, the core does not cause it to bulge. Aggregate is not exposed at the outer surfaces because there is no leaking of grout from the forms, since there are no forms by reason of the shell being used in the manner described. Also, improved appearance is realised by using fine aggregate for the shell and coarse aggregate for the core.

The present invention also offers advantages over precast concrete because of lower hauling and erection costs realised by the lighter weight of the shells to be handled, the use of smaller, lighter equipment—in itself cheaper—to handle the same, and also provides an equal or better appearance for substantially the same reasons mentioned above. A further advantage over precast concrete is realised in the simplified fashion of accomplishing permanent column to beam connections because precast concrete frequently requires the welding of steel clips together in order to maintain the connections in a permanent state. The present invention by contrast, provides an integral core bonded to the shell, thus establishing the permanent connection.

While the invention has been described in considerable detail in the foregoing specification, it is to be understood that various changes may be made in its embodiments without departing from the scope of the claims appended hereto.

WHAT WE CLAIM IS:—

1. A method of building a concrete structure formed of a number of concrete shells interconnected by a core bonded to inner walls of the shells, comprising the steps of aligning the shells in the structure so that they form a core receiving chamber and pouring concrete into the core receiving chamber in juxtaposed intimate bonding relation with the inner walls of the shells wherein the shells are each formed by assembling a number of forms to define the shell, applying a retarder to that portion of the forms defining the inner walls of the concrete shell, pouring concrete into the forms, allowing the concrete to set until the main portion of the concrete shell is set sufficiently to permit removal of the forms, removing the forms from the concrete shell and removing cementitious material and retarder from the inner walls of the concrete shell thereby exposing the aggregate embedded in the set concrete.

2. A method according to claim 1 wherein said removing step includes washing the retarded cementitious material away with a stream of water.

3. A method according to claim 1 or 2 including the step of inserting reinforcing steel in the form before the first step of pouring.

4. A method according to claim 1, 2 or 3

including the step of inserting reinforcing steel in the core-receiving space before the second step of pouring.

5. A method of building a prestressed, reinforced concrete structure according to claim 4 wherein a force is applied to the reinforcing steel at a predetermined time relative to the setting of the concrete.

6. A method of building a concrete structure substantially as herein described with reference to the accompanying drawings.

7. A concrete structure made according to any one of the preceding claims.

For the Applicants:
RAWORTH, MOSS & COOK,
Chartered Patent Agents,
38, Sydenham Road, Croydon, Surrey,
and
75, Victoria Street, Westminster,
London, S.W.1.

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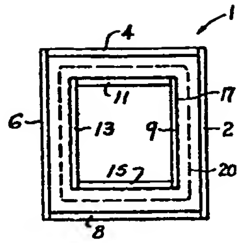

Fig. 1

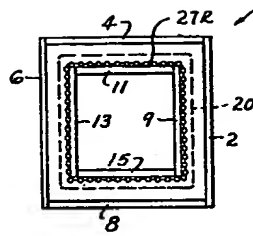

Fig. 2

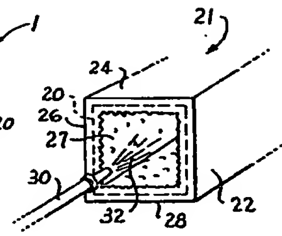

Fig. 3

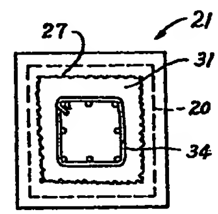

Fig. 4

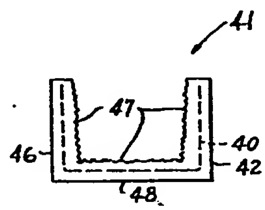

Fig. 5

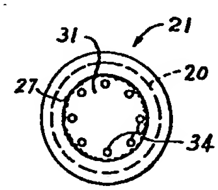

Fig. 6

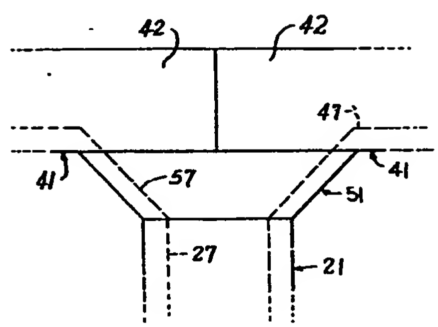

Fig. 8

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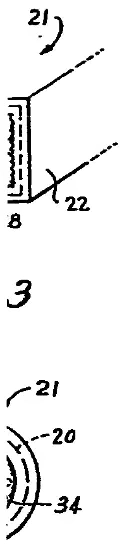

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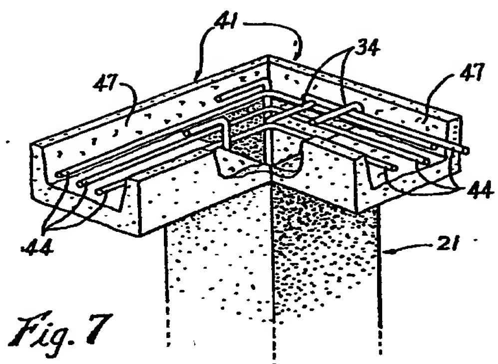

Fig. 7

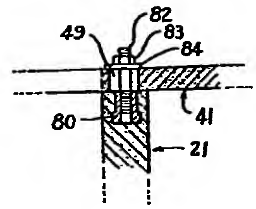

Fig. 9

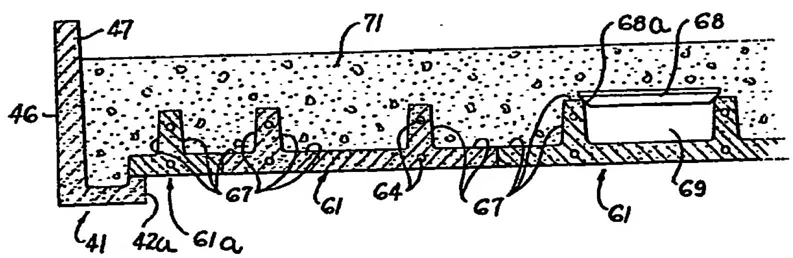

Fig. 10

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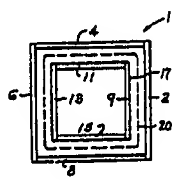

Fig. 1

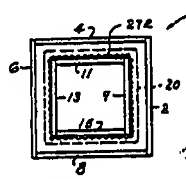

Fig. 2

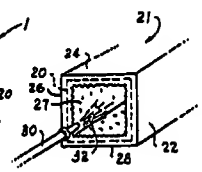

Fig. 3

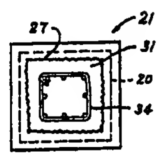

Fig. 4

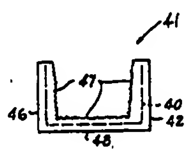

Fig. 5

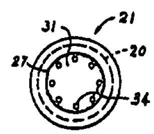

Fig. 6

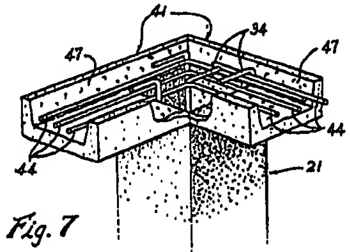

Fig. 7

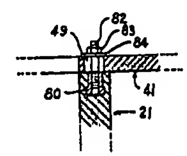

Fig. 9

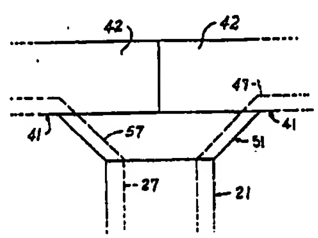

Fig. 8

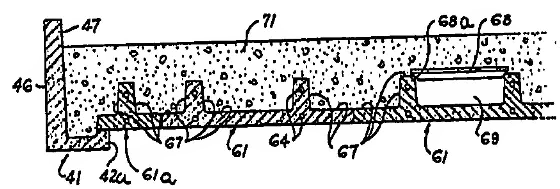

Fig. 10